A Review of Some Causes and Consequences of Mortality Change

Farewell Lecture

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A Review of Some Causes and Consequences of Mortality Change

Farewell Lecture

By

Hans O. Hansen

Abstract

(368 words)

This lecture comments on long term development of Danish and Swedish cohort mortality from age 60 and beyond. How does long term mortality change relate to current and expected population aging? And what impacts does mortality change (ideally) have on annual cash payouts of personal reserves in funded pension schemes? What should we expect regarding future development of old-age mortality?

What is the background of empirical long term development of cohort mortality from age 60 and beyond? This issue brings the entire life span from birth to extinction of birth cohorts into focus. I document the range of cohort based mortality variation since the mid-eighteenth century up now in populations not exposed to sudden chocks in historical time, for example in terms of natural disasters or wars with immediate major impact for survivorship. Three distinct groups of mortality patterns come to surface viz. extremely high mortality, very low mortality, and transition from high to low mortality.

To what extent may latent individual survivorship explain observable long term mortality change across the elected birth cohorts? To discuss this issue I propose a hazard model featuring a gamma-distributed individual congenital frailty; age-dependent baseline mortality; and external factors with/without impact for selection in human survivorship. The model may be described an extension to work by Gompertz (1825), Makeham (1860), Cox (1972), and an application by Vaupel et al. (1979). Likelihood estimation of parameters is not an option because of heterogeneity. I identify latent baseline mortality while fitting the model to observable cohort mortality using stochastic micro simulation. The quality of the model-based individual life times to describe heterogeneous empirical cohort mortality is truly amazing; which leaves us with a consistent theory, rather than with a hypothesis of empirical mortality change. For a detailed technical outline with a summary of results cf. Hansen (2008).

Within the biological restraints of the identified baseline mortality medical technology and knowhow may shield against adverse environmental impact, thus reducing natural selection in human survivorship; letting frail individuals live on to higher age than ever seen in history. Reducing natural selection by use of modern medical technology and knowhow may have far reaching and costly health impacts among the elderly in an era of rapid population aging.

Contents

Background

- Discovery and disclosure of very rich and unique historical population data in Iceland while working out Master Thesis (history) (Supervised by Prof., Dr. Phil. Kristof Glamann back in 1966-67).

- Institute of Statistics
  - Assistant professor (Videnskabelig assistent) (Demography) 1969 to 1973
  - Associate professor (Lector) (Demography) 1974-1997

- Department of Economics, Associate professor (Lector) (Demography) 1997-2009

- Much confusion about current and expected population aging and mortality change

Problem

- This lecture comments on long term development of Danish and Swedish cohort mortality from age 60 and beyond.
- How does long term mortality change relate to current and expected population aging?
- What impacts does mortality change (ideally) have on annual cash payouts of personal reserves in funded pension schemes?
- What should we expect regarding future development of old-age mortality?
- What is the background of empirical long term development of cohort mortality from age 60 and beyond?

Approach

- Model-based empirical analysis and projection
- Calculation of actuarial present values of capital flows in presence of mortality
- Estimation and stochastic micro-simulation of survivor processes in continuous time

Long term development of cohort mortality in Denmark, Sweden, and Japan from age 60 and beyond

Figure 1
Lexis diagram – Observational plan of data and analysis

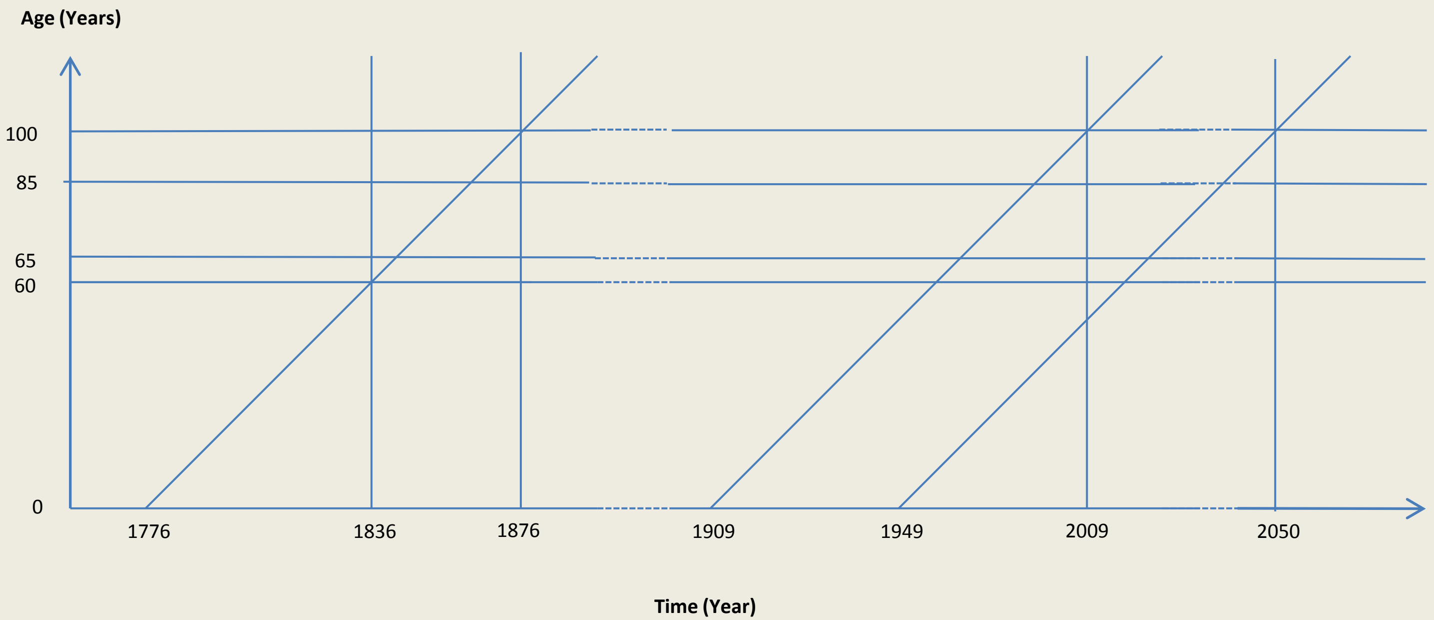
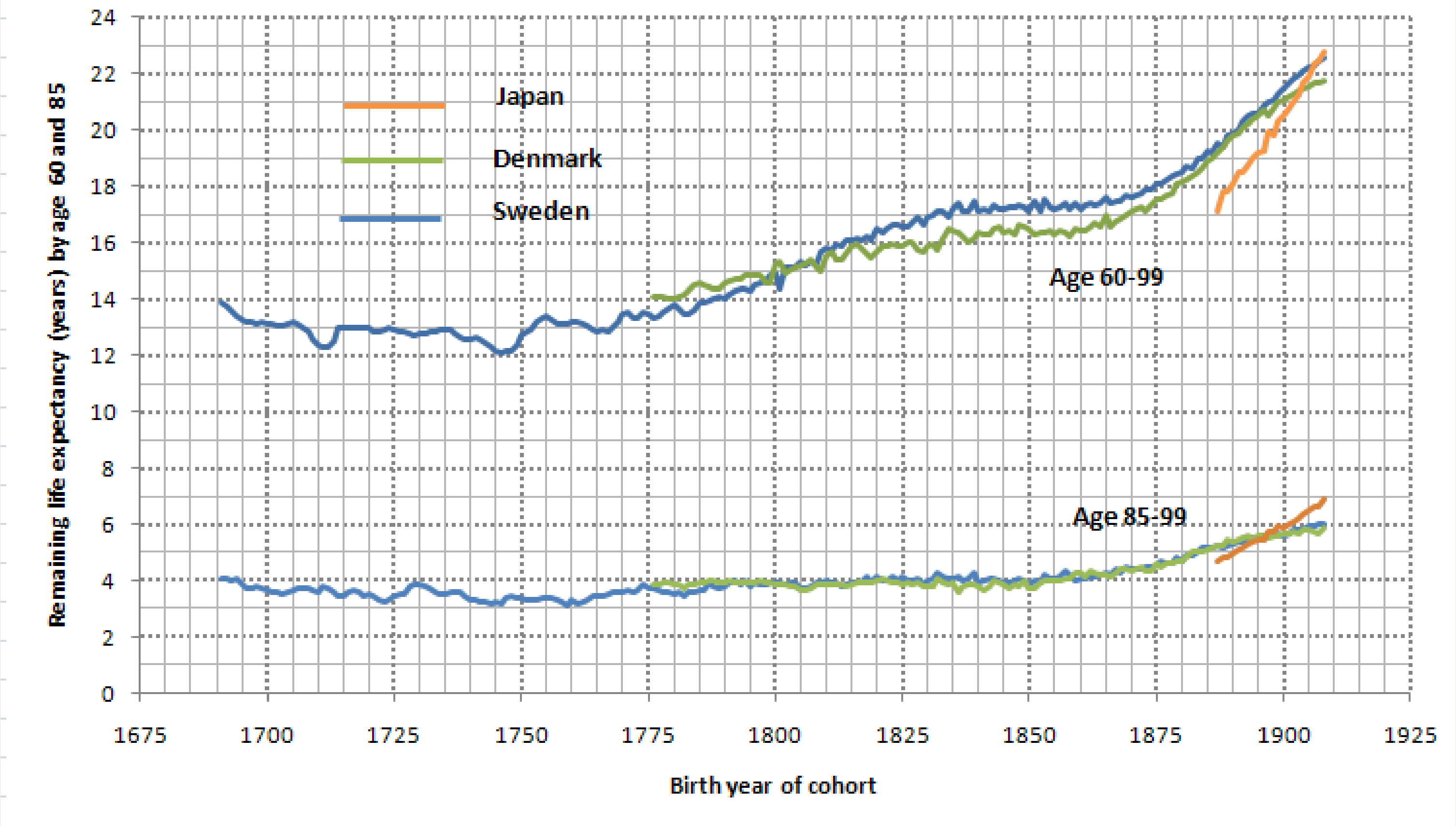


Figure 2

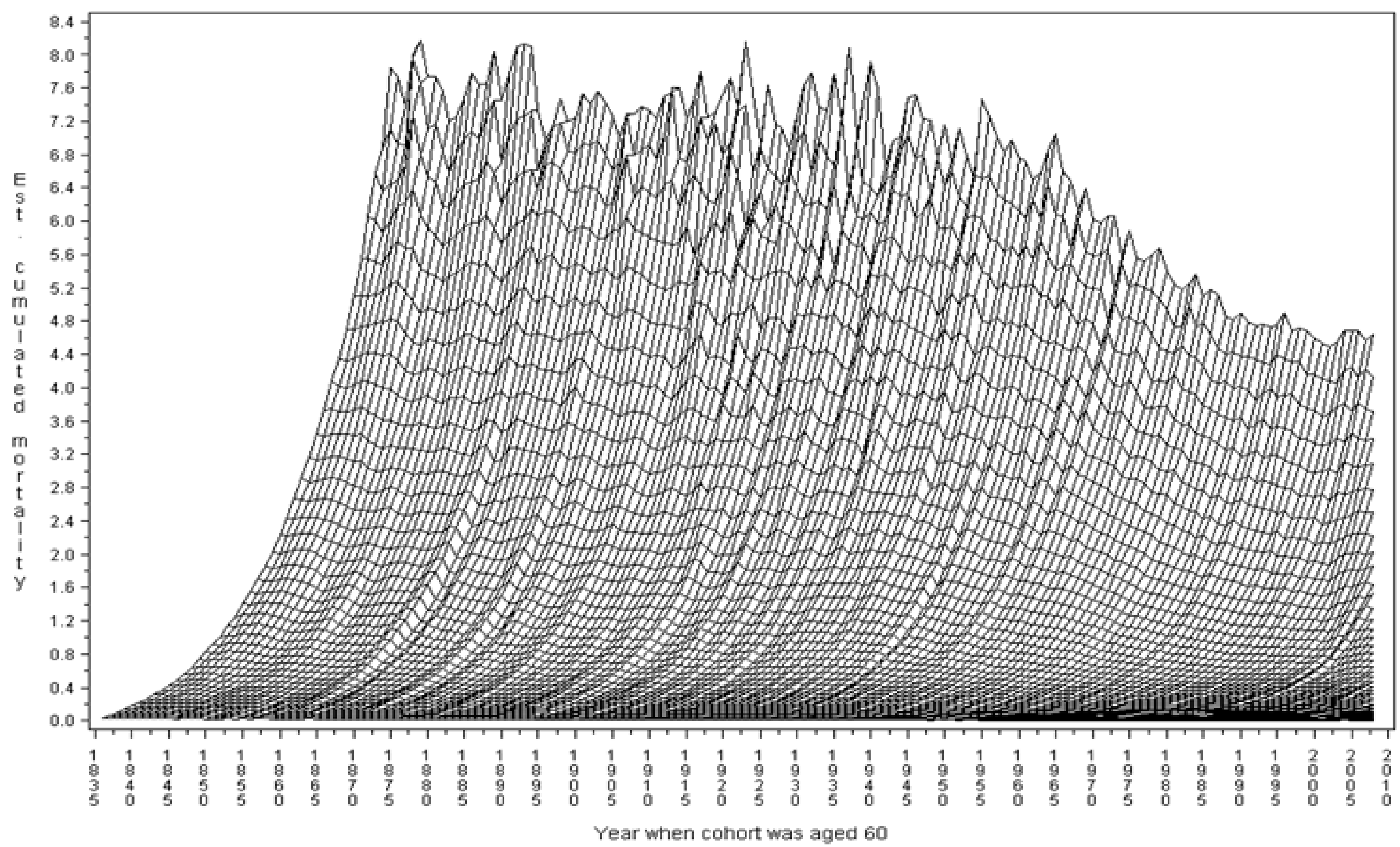
Expected remaining life time by ages 60 and 85 among female cohorts born in Sweden 1691-1909, Denmark 1776-1909, and Japan 1887-1909

(Truncated by age 100)



Source. Computations based on data from *Human Mortality Database.* University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de (data downloaded on June 2009)

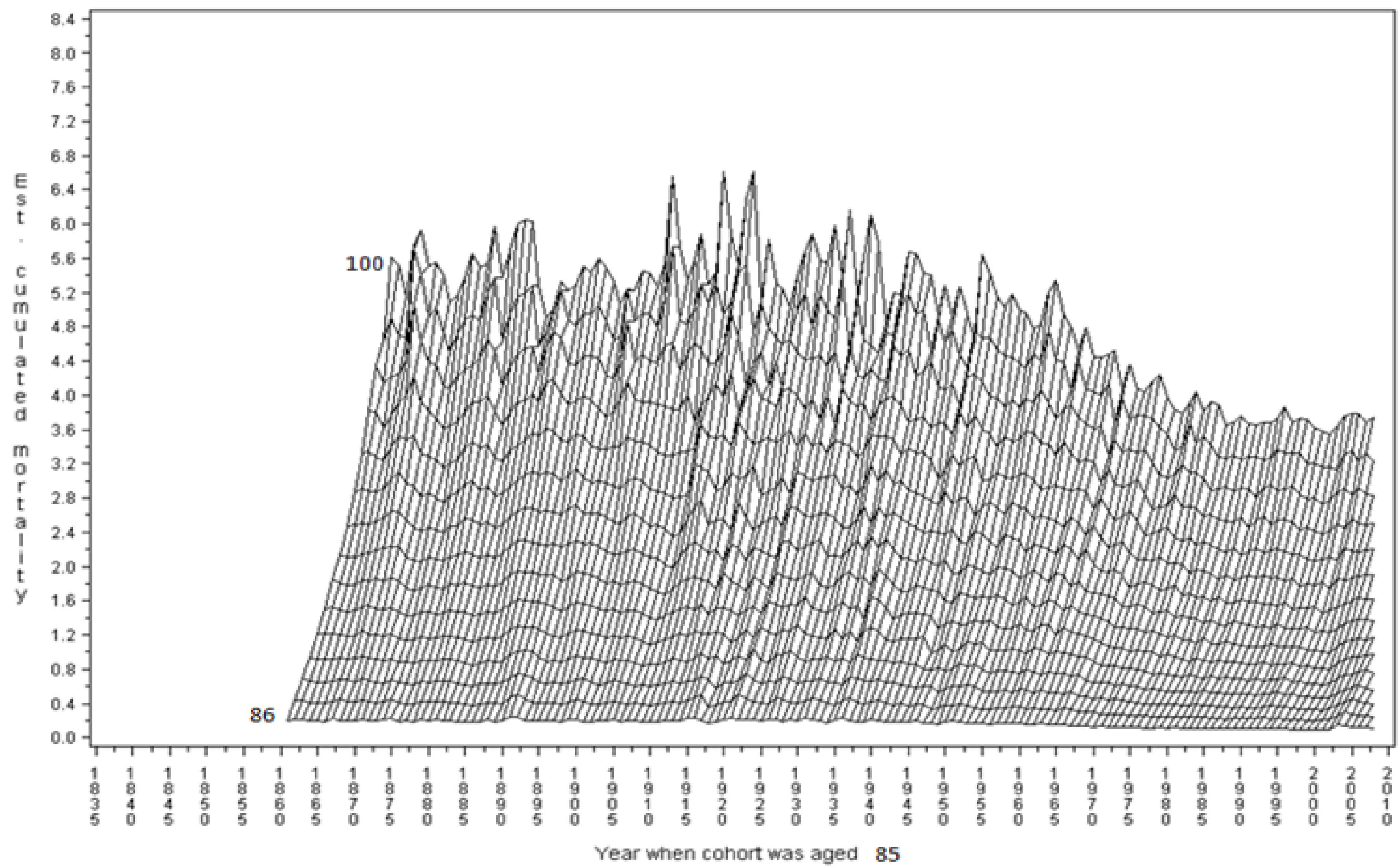
Figure 3
Estimated cumulated mortality across age [60,100[of Danish female cohorts born between 1775 and 1948



Source. Cf. figure 2

Figure 4

Estimated age-cumulated mortality across age [85,100[of Danish female cohorts born between 1775 and 1948



Source. **Cf. figure 2**

Some impacts of mortality change

A Brief review of fertility and mortality as determinants of population aging

How does historical mortality change impact on annual cash-payouts of pension reserves?

The simple life model with reproduction

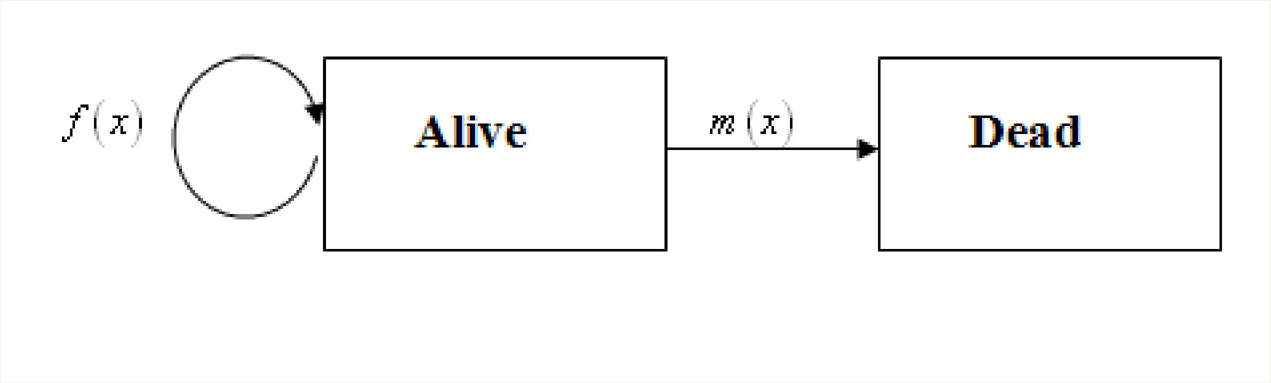
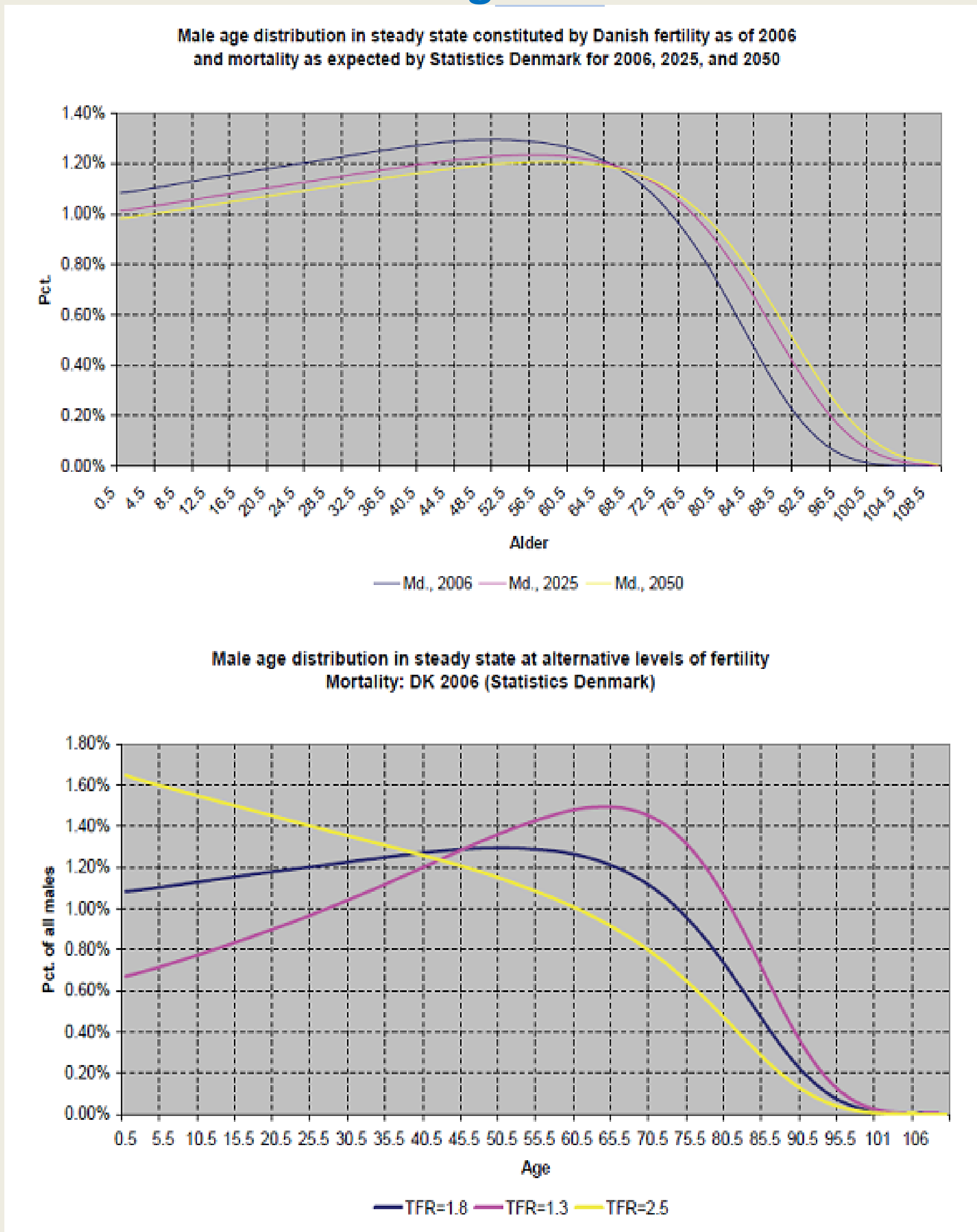
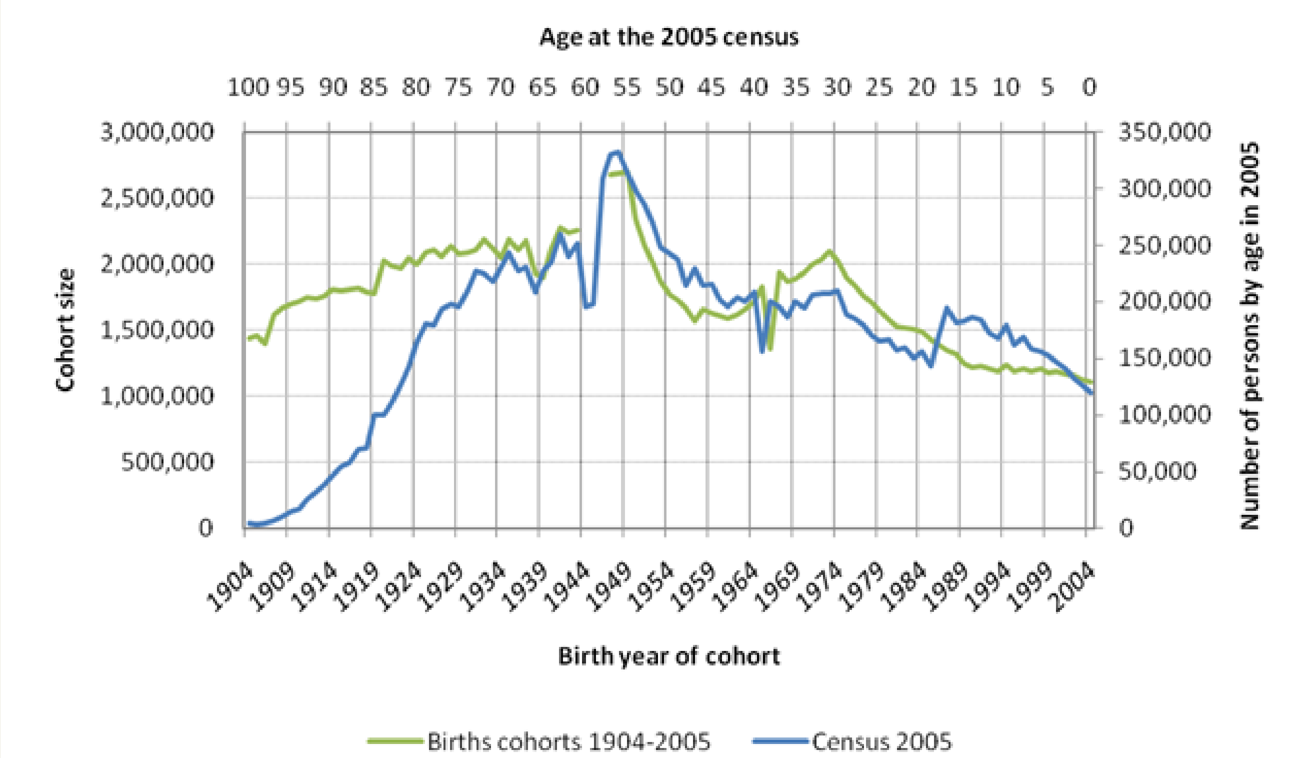


Figure 5



Source. Hans O. Hansen (2006). *The Demography of Ageing of Human Populations*. Lecturing note – Demography 1 (Univ. of Copenhagen, Dept. of Econ.)

Figure 6
Comparing size of birth cohorts and number of survivors at the 2005 Census of Japan



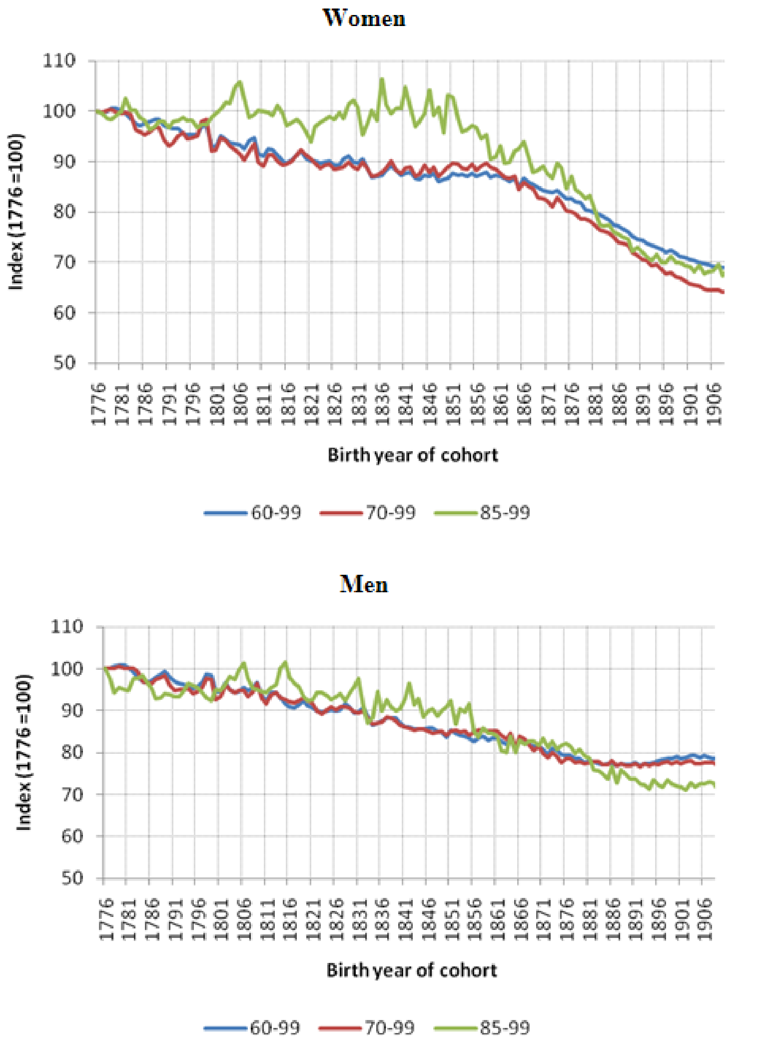
Source. Human Mortality Data Base; Statistical Bureau, Policy Planning (Statistical Standards) and Statistical Research and Training Institute, Japan

Up to age 70 cohort size has been the dominant factor in shaping the age distribution of Japan as of the Population Census of 2005. After age 70, mortality is the critical part.

Because of augmenting birth cohorts from 1904 to 1950, we should expect an increasing number of elderly people and centenarians in the decades to come.

Figure 7

Indexed values of cash-payouts if retiring at age x, x=60, 70, 85; on condition of a fixed personal reserve (pension fund), real interest equal to 2 pct., and homogeneous mortality in all other respects but *age* and *gender* (*sex*)



Source. Computations with DEMOPACK using data from Human Mortality Database

Some causes of mortality change

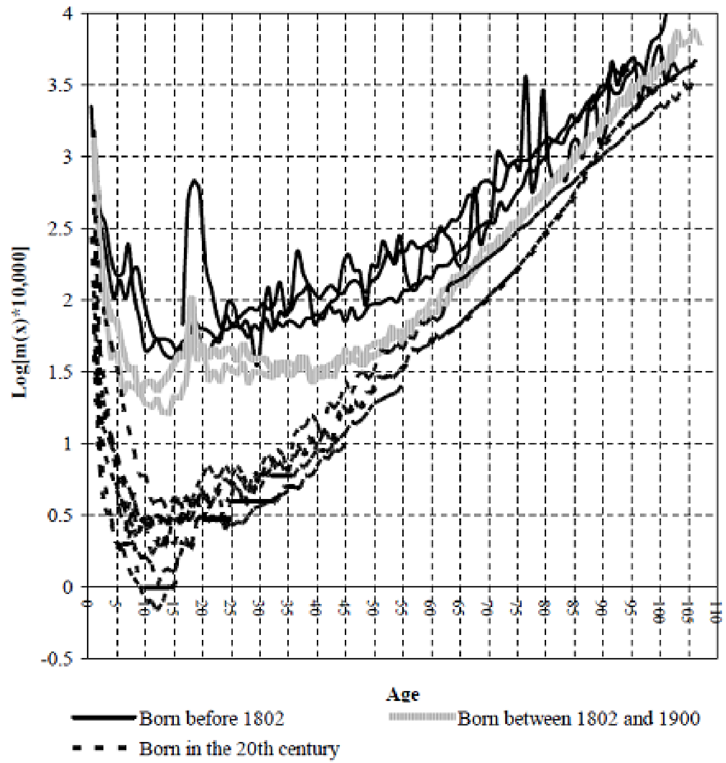
- We now look into some empirical levels and age patterns of cohort mortality
- We present a model of selection in human survivorship
  - How well does the model describe extreme variation in cohort mortality?
  - Identification of a baseline hazard independent of time and gender
  - What does the model predict regarding selection and health among survivors?

Introductory remarks

- **Historical mortality change has limited impact on *expected* annual cash pay-out of personal pension reserves.**
- **However, even if mortality were homogeneous in all other respects but age and gender (sex), expected remaining life time would still be subject to uncertainty. If we relax the assumption of homogeneity, the variance should be much greater. This poses a more general question.**
- **What evidence do we have of *ex post* impacts of heterogeneity and selection of human life courses (individual level) or survivorship of heterogeneous birth cohorts (aggregate level)?**
- **To address this issue we may begin by taking a close view of life course mortality of elected empirical birth cohorts fulfilling the following requirements.**
- **The cohorts should document the range of human mortality on reliable historical record up to now**
- **The cohorts must not have been exposed to noticeable environmental shocks with no impact for selection i.e. no "tsunami mortality".**

Figure 8

Empirical mortality (Semi-logarithmic scale) of elected female cohorts born before 1802, and in the course of the nineteenth and twentieth centuries.



Source.
Based on data from Berkeley Mortality Data Base and mortality recovered by Hansen 2004.
Note.
Cohorts born before 1802: Iceland 1767; Sweden 1751, 1801
Cohorts born between 1802 and 1900: Denmark 1835; Sweden 1851
Cohorts born in the twentieth century: Sweden and Denmark 1901, 1944; Japan 1950, 1960, 1970, 1980, and 1990

To study what part genetic heritage and environment may have played as factors in extreme empirical mortality change as evidenced in Figure 8 the following hazard model picture individual mortality , *x* denoting *age* and *t* representing *time*.

$$m_i(x,t) = z_i \cdot m(x,z=1) \cdot \varepsilon(t) + \delta(t)$$

Description of the elements of the model+

Statistic	Interpretation	Assumptions
i	Individual number	
x	Age	
t	Time	
$m_i(x,t)$	Individual death risk	
z_i	Individual congenital frailty	$Z_i(s.v.) \sim Gamma(\alpha,\beta,\kappa=0)$ $\Rightarrow E[Z_i]=\alpha\beta; Var[Z_i]=\alpha\beta^2$
$m(x,z=1)$	Baseline mortality (Raw or normalized form)	
$\varepsilon(t)$	Environmental factor with impact for selection	The two environmental factors are mutually exclusive
$\delta(t)$	Environmental factor without impact for selection	

+) Source. Hansen (2008)

- **The fact that human mortality is differential across individuals rules out likelihood estimation of the parameters and elements on fitting the model to empirical cohort mortality (Figure 8).**

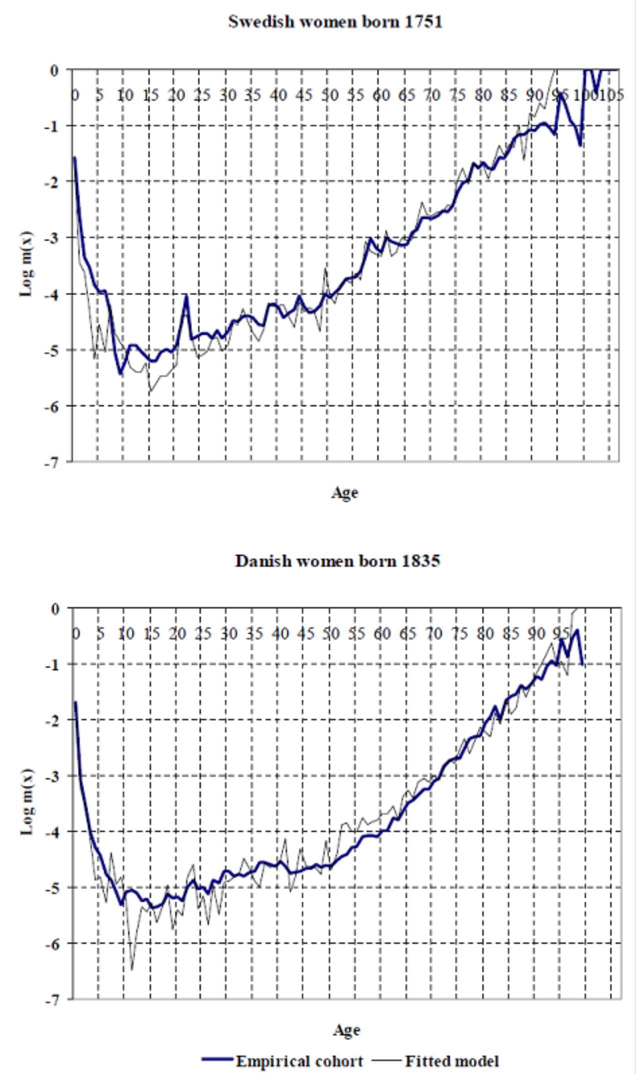
- **Instead we resort to stochastic micro-simulation cf. Hansen (2000).**

- **For technical details and a full summary of results cf. Hansen (2008).**

- **Here follows a few examples of the capability of the model to describe empirical cohort mortality**

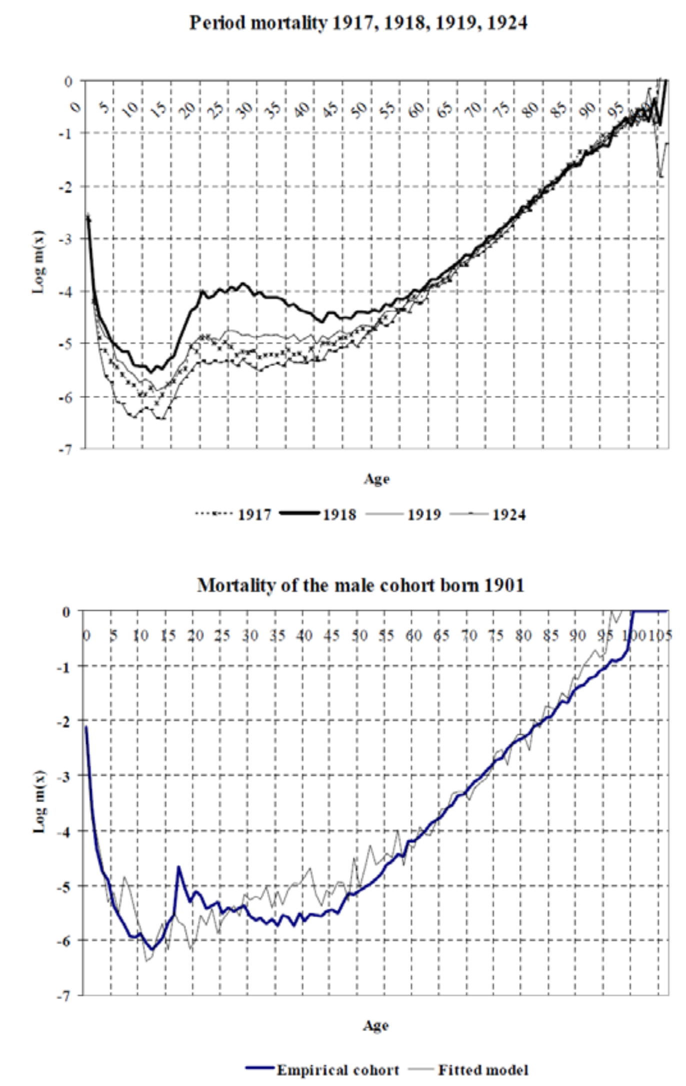
Figure 9

Empirical and fitted mortality by age.
Swedish women born in 1751 and Danish women born in 1835



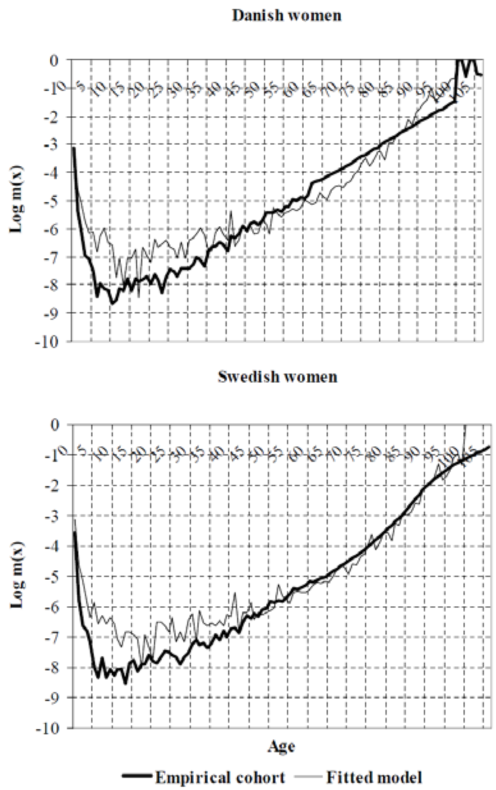
Source. Empirical mortality: Berkeley Mortality Data Base.

Figure 10
Period mortality of Swedish men between 1917 and 1924 and empirical and fitted mortality of men born in Sweden 1901.



Source. Berkeley Mortality Data Base

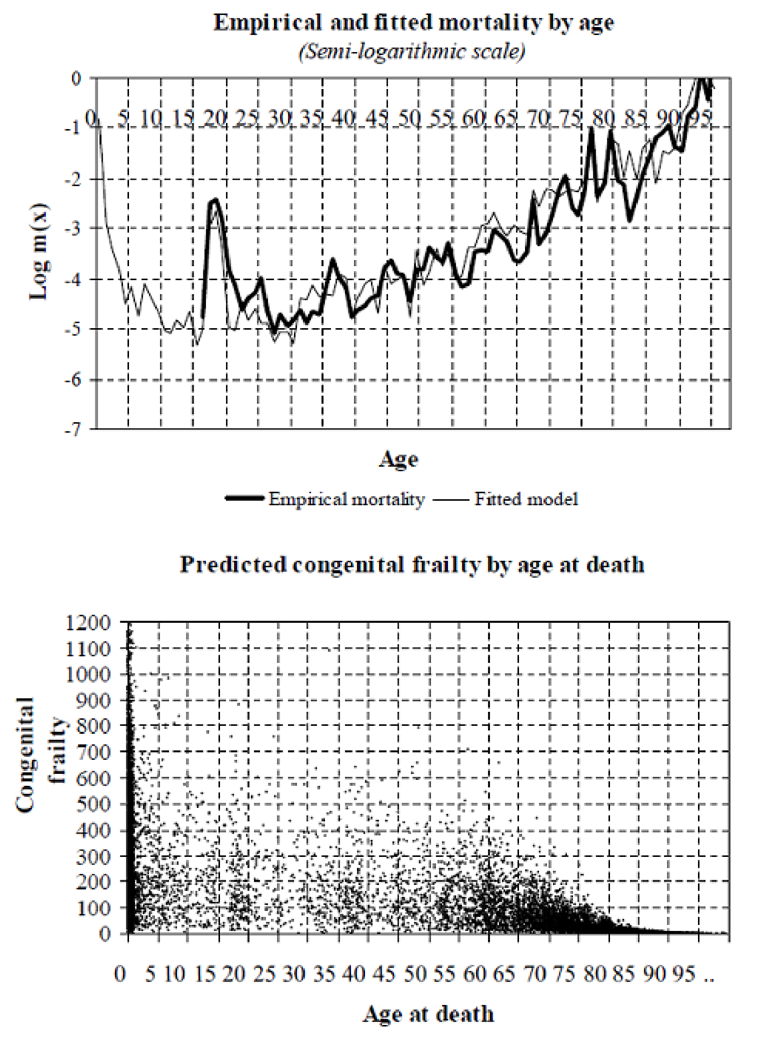
Figure 11
Empirical and predicted mortality of the female cohorts born in Denmark and Sweden 1944



Sources. Up to age 61: Computations base don data from Berkeley Mortality Data Base; age 61 and beyond: Computations based on anticipated mortality by Statistics Sweden (2205, 2006) and Statistics Denmark (unpublished).
1) The ruptures in empirical mortality around 2005 are associated with data issues rather than with mortality change.

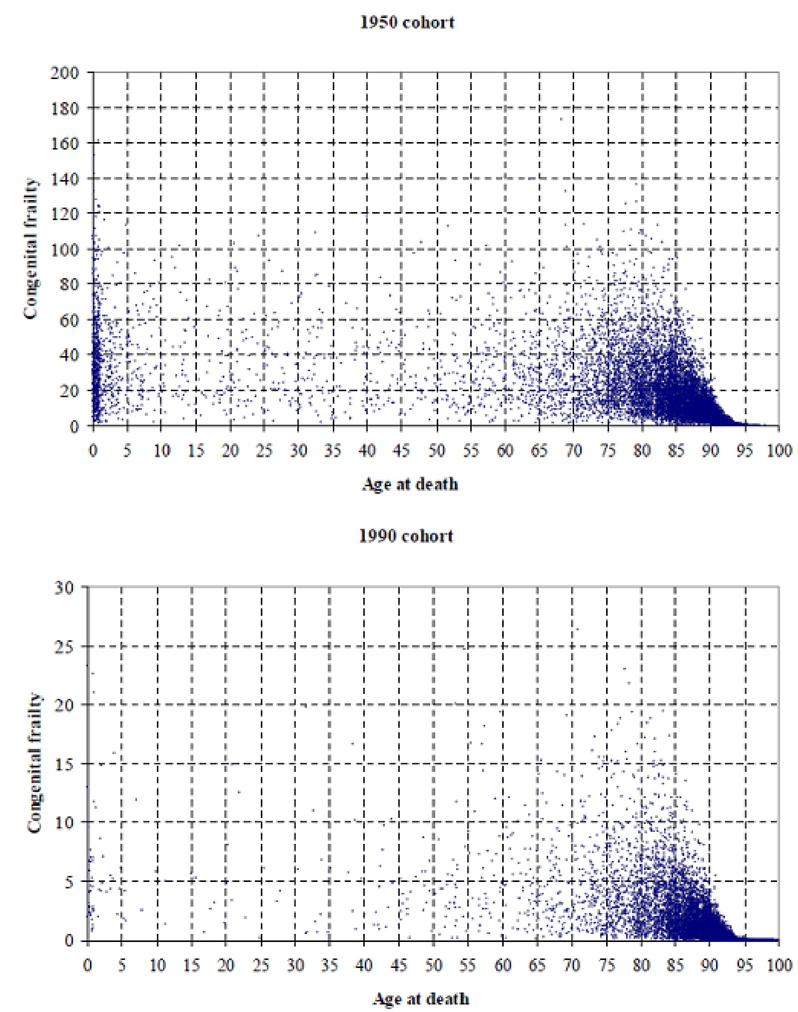
Figure 12

Fit of the hazard model to empirical mortality of the Icelandic female cohort born in 1767 and congenital frailty by predicted age at death



Source. Based on data recovered by Hansen (1967).

Figure 13
Congenital frailty by predicted age at death among Japanese women born in 1950 and 1990.



Source. Computations based on data from Berkeley Mortality Data Base.

Closing remarks

- As this lecture is drawing to a close I would like to thank you all for coming.
- I appreciate the more than ten years of peaceful coexistence with my economic colleagues in the Dept. of Econ., even though I could have wished for more professional interaction. After all, without population there would be little economy and economics. On the other hand, no population grows out of the thin air: there must be material basis. So our disciplines depend on one another.
- When I started in the Dept. of Stat. with a professional background in history, focused on population change and economic and social history, I had to develop and brain enhance on substantial technical issues to contribute to academic demography. My first priorities were to establish a broad and solid background in information processing, statistical computing, and elementary theoretical statistics. Over the years I have benefited greatly from communication with Arne Facius, Kjeld Simonsen, Aage T. Andersen, and lately Ahmed Rahka. I appreciate their cooperation and their willingness to sharing their knowledge.
- I also recognize the cooperation with many external examiners over the years such as U. Christiansen and lately L. Borchsenius, O. Zacchi, A. Schaumann, and H.E. Hansen. We should not forget Patrick Rosenquist in the Study Administration either.

- What I might have missed in professional interaction with co-employees, to not a small extent has been richly compensated in working with very many students over the years. Harald Westergaard (prof. 1886-1924) and Hans Cl. Nybølle (prof. 1936 – ca. 1940), together representing the golden age in Danish academic demography, both claimed that to be effective empirical demography and population studies must be based on consistent and relevant statistical modeling. The activities in Dept. of Stat. actually gave few clues in this direction. However, with the nomination of Jan Hoem as professor of actuarial statistics in 1976 and with my literally marrying into mathematical statistics, the tides changed; leading, on one hand to a modern text book and learning system based on beaten tracks from the theory of stochastic processes in continuous time and fully computerized, enabling students, mostly with limited technical background, to address population issues of great complexity and of substantial public significance and interest; resulting in not a few novel contributions in the modest academic framework of master theses in economics. This cooperation has been professionally and personally rewarding, not least for me. It is good to learn that most of the students have been doing well in their labor markets
- Last but not least, I would like to thank the leadership of the Dept. of Econ. for offering me the opportunity to give this lecture and the reception that we all look forward to. In some recent minutes from a meeting on cooperation within the Dept. I read that everybody, leadership and employees, endeavor a good and cooperative atmosphere in the workplace. Department of Economics has been a good workplace for me. I have been fortunate enough to have my work as my hobby for more than forty years. So, Peder, on behalf of the Dept., please accept my thanks for the treatment and the treat in terms of the reception, which we shall enjoy downstairs.